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OPERATING DIESEL LOCOMOTIVES UNDERGROUND IN EUROPEAN MINES

BY

J. H. EAST, JR.

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Operating Diesel Locomotives Underground in European Mines[1]

By J. H. East, Jr.[2]

INTRODUCTION

Diesel locomotives have been used successfully in underground mines of Europe for 18 years, and much has been written on the technical details of the design of these machines and the safeguards provided by the manufacturers. The actual conditions under which the Diesel locomotives are used have not been publicized as well and consequently are not well-known. In 1945 the writer observed numerous Diesel locomotives working underground in coal and metal mines of several European countries and was favorably impressed with the practical approach to the safe use of this type of equipment.

Recent statistics showing the number of Diesel locomotives in use are not available now because of the World War, but the extent to which this type of mine locomotive was used immediately before the war is indicated by table 1, which classifies the number of locomotives used in several countries according to the type of power, such as compressed air, Diesel, and electric.

TABLE 1. - Mine Locomotives used in underground coal mines in some European countries

Country	Year	Type of power and number in use			
		Diesel	Compressed air	Electric	Gasoline
Germany:					
Western.	1938	547	1181	1503	41
Eastern.	1938	55	18	298	40
Belgium...	1939	114	18	33	19
France....	1935	269	164	273	?

Mining conditions observed by the writer in the European countries are very different from those in most coal-mining districts of the United States. The surface plants are larger and are permanently constructed of brick or concrete; numerous coal beds are worked through one shaft; the crosscut rock tunnels or levels, driven to intersect the coal beds, are lined with brick or concrete blocks where needed instead of timber; the coal beds dip more steeply and are not as thick as in most fields of the United States.

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The longwall system of mining followed by back filling is the usual mining method; the output of coal per underground worker is much less; and more workers are employed away from the actual mining face than is customary in American practice.

The mining conditions observed in several countries where Diesel locomotives are used underground are described briefly. Statistics, where available from official sources, are quoted to show the classification of mine locomotives in use according to the type of power.

Germany

Diesel locomotives were introduced into German underground coal mines in 1927, and by 1933 reports indicate that 78 Diesel locomotives were in use in the Ruhr district alone. The national policy of not using materials that need be imported prevented a more rapid increase, as fuel oil is not produced in substantial amounts in Germany. The official tests have shown that, when correctly designed and operated under certain conditions, Diesel locomotives are as safe to use in gassy coal mines as electric storage-battery locomotives and much safer than the trolley-type locomotives.

The extent to which Diesel locomotives were used in German coal mines can be seen in tables 2 and 3. Four hundred eighty one Diesel locomotives or 18.8 percent of the total, were used as main-line locomotives in western German mines, and 52 Diesel locomotives or 14.5 percent of the total were used on main lines in eastern Germany.

The mining laws of Germany do not specify ventilation requirements when Diesel locomotives are operated underground, but the inspector for each district is empowered to make regulations for each mine. Usually, the Diesel locomotives are operated in intake air without any other restrictions. However, in mines that are rated as "very gassy," only compressed-air-operated locomotives are permitted, unless the locomotives operate entirely in intake air.

The mines in the Saar district are very gassy, and as a result very few electric locomotives of any type are in use. In fact, the use of electricity is not permitted underground in some of the larger mines, except at special installations, such as permanent pump stations. Diesel and compressed-air-operated locomotives are about evenly divided as to the number in use in the district (table 2).

TABLE 2. - Mine locomotives in use underground in coal mines in western Germany, 1938

	Ruhr		Aachen		Saar	
	Number	Horsepower	Number	Horsepower	Number	Horsepower
Main line						
Electric, trolley.....	1163	48201	27	1046	16	595
cable reel...........	33	1203	5	210	0	-
Compressed air........	673	19566	37	1062	125	3019
Diesel................	279	10914	73	2732	129	3475
Total..............	2148		142		270	
Gathering						
Electric, cable reel..	259	2347	0	-	0	-
Compressed air........	342	3996	4	54	0	-
Diesel................	61	707	1	8	4	34
Total..............	662		5		4	
Gasoline..............	28	492	0	-	13	?

TABLE 3. - Mine locomotives in use underground in coal mines in Eastern Germany, 1938

	Upper Silesia		Lower Silesia		Saxony	
	Number	Horsepower	Number	Horsepower	Number	Horsepower
Main line						
Electric, trolley.....	237	9577	31	1255	20	841
Compressed air........	0	-	0	-	18	515
Diesel................	9	227	41	1334	2	85
Total..............	246		72		40	
Gathering						
Electric, cable reel..	7	31	3	15	0	-
Compressed air........	0	-	0	-	0	-
Diesel................	1	22	2	32	0	-
	8		5		0	-
Gasoline..............	18	246	22	4030	0	-

The Maybach mine is one of the large mines in the Saar district and is very gassy. The coal production formerly averaged 4,500 tons of clean coal daily; the production is secured from 12 beds of coal ranging from 18 inches to 8 feet in thickness. The principal shaft is 2,285 feet deep, with crosscuts at 333-foot (100-meter) intervals. The dip of the coal beds ranges from 8° to 12° at the present working depth and gives approximately 1,000 linear feet of coal between levels normal to the strike. The longwall method of mining is used exclusively; shaking conveyors remove the coal from the longwall face, and belt conveyors take the coal to the car-loading station near the haulage crosscut. The loaded coal cars are dropped by gravity to an assembly yard, and either a compressed-air-operated or a Diesel locomotive pulls the train to the shaft bottom. In this mine, the compressed-air-operated locomotives are used interchangeably with the Diesel-driven type. The crosscut haulage tunnels are rather long and are used as ventilating-air intakes. The district State mine inspector believed that electric locomotives of the trolley type would undoubtedly cause an explosion in this mine if used in the entries, as outbursts of gas are not uncommon.

In all the haulage tunnels observed, the ventilating-air current was sufficient to dilute and dissipate the exhaust fumes from the Diesel engines; no odors were discernible in any of the mine workings. The safety devices on the Diesel locomotives were well-maintained, and the water level in the exhaust-gas washers was maintained by refilling each time the locomotive returned to the hoisting shaft. The labyrinth-type spark arrester was used on these locomotives, and it was stated that the arresters were cleaned superficially at the end of each shift and thoroughly cleaned on idle days.

Belgium

The coal beds of Belgium are thinner and more broken by faults than in any other European country; gas is more of a problem, with the result that mining laws are more restrictive, particularly as regards the use of electricit underground. As late as 1930, only seven electric locomotives were used underground in coal mines. Small gasoline locomotives were used but were not satisfactory and were replaced with Diesel locomotives after their development in Germany.

The trend in mechanical haulage is shown by comparing the official statistics covering mine locomotives shown in tables 4 and 5. The statistics prior to 1939 did not differentiate between gasoline and Diesel locomotives, but the number of internal-combustion engines used in this service increased from 73 in 1935 to 133 in 1939, of which 114 were of the Diesel type.

TABLE 4. - Number of locomotives used underground in coal mines, 1939

District	Diesel	Gasoline	Compressed air	Electric	Total
Mons.......	38	10	0	0	48
Centre.....	3	0	0	0	3
Charleroi..	18	6	4	0	28
Namur......	0	2	0	0	2
Liege......	12	1	0	0	13
Campine....	43	0	14	33	90
Total.	114	19	18	33	184

TABLE 5. - Number of locomotives used underground in coal mines, 1935

District	Diesel[1] or gasoline	Compressed air	Electric	Total
Mons........	15	12	0	27
Centre......	2	0	0	2
Charleroi...	17	4	0	21
Namur.......	3	0	0	3
Liege.......	19	0	0	19
Campine.....	17	10	29	56
Total.	73	26	29	128

[1] Official statistics of types of mine locomotives did not differentiate between gasoline- and Diesel-engine power prior to 1939.

The Campine, or North district, is also called Limbourg; it is newer and mechanized more completely than other Belgian coal fields. The coal beds are folded in zigzag fashion but are not badly faulted. The longwall system of mining is used almost entirely; the coal is mined with compressed-air picks weighing 12 pounds and loaded on shaking conveyors that are operated with compressed-air motors. The coal is transported to the gangway and loaded into cars or taken by a belt conveyor to a loading station. Both Diesel and electric locomotives are used for haulage, but if electric locomotives are used, they are operated only in intake air and are not permitted in return airways.

One of the larger mines in this district, the Winterslag, has 26 coal beds, but only 8 are being worked because of a labor shortage. The coal beds range from 16 inches to 4 feet in thickness and average 2 feet. The coal is opened by a vertical shaft with crosscut tunnels at 2000-, 2200-, and 2450-foot depths; the panels are 650 to 1300 feet long depending on the fault conditions.

The haulage tunnels are very long in this mine, requiring high-speed transportation to handle the coal. With the permission of the mine inspector, an excess amount of intake air is coursed through these tunnels and electric locomotives are used, pulling trains of 50 loaded 1-ton-capacity cars at a speed of 18 miles an hour. The locomotives weigh 10.5 tons.

The Diesel locomotives used in this mine usually are not equipped with water-cooling or other devices to cool or absorb the toxic gases from the exhaust fumes; dependence is placed entirely on ample ventilation to remove and dilute the fumes. The engines are not permitted to idle, except in the main haulage tunnels. Tests for carbon dioxide (CO_2) and carbon monoxide (CO) are not made.

Some mines in this field use electric locomotives in intake air and Diesel locomotives in the return air; in this case the mine inspector requires that the Diesel locomotives be equipped with spark and flame arresters and that they be maintained in a permissible condition.

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The mine officials who were interviewed are fearful of an explosion if electric locomotives are operated off intake air, and for this reason their use is restricted to the rock-haulage tunnels, which are always on intake air. Diesel locomotives are preferred for use underground, except where high speed is essential.

The Moes Co. at Waremme is said to be the only manufacturer in Belgium of Diesel locomotives for underground use. The latest model is known as the DLM4; it was placed in service just before the German occupation. The locomotive weighs 10 tons, and the Diesel engine develops 56 horsepower. It is a 4-cycle engine and requires 128 liters (4.5 cubic feet) of air and 3.3 grams (0.00726 pound) of fuel oil per minute per brake-horsepower. It will transport 100 loaded cars per trip as compared with 50 cars per trip pulled by the 2-cylinder, 2-cycle Ruhrthaler locomotives. The capacity of the cars is 850 kilograms, and the deadweight of the car is 500 kilograms, making the total weight of a loaded car 1,350 kilograms or 2,970 pounds. The exhaust gases pass through a water filter before discharging into the atmosphere.

France

The principal coal-mining districts of France, in the order of their 1937 production, are Nord and Pas-de-Calais, Moselle, and Loire with 60 percent, 13.6 percent and 7.1 percent, respectively, of the total domestic production. The coal beds are folded steeply and faulted, which causes very difficult mining conditions. The dip of the coal beds varies from horizontal to vertical, sometimes in the same mine. In one locality there are 51 workable coal beds containing 154 feet of coal. Most of the beds are less than 3 feet in thickness, except in local occurrences where beds come together and form one bed 10 to 12 feet thick.

The mine plants are large and frequently include byproduct coke ovens and briquetting plants, hydrogenation plants, chemical plants, and commercial electric-power plants in addition to the tipples and cleaning plants for handling the raw coal as it comes from the mines.

The coal is usually mined by one of the four methods shown below, but the longwall system is generally used:

a. Advancing to the rise.
b. Advancing to the dip.
c. Advancing on the strike.
d. Longwall.

Back filling is the general practice and is required by law in most instances. The shafts are sunk the required depth, and crosscut tunnels are driven to intersect the various coal beds. The crosscut tunnels usually serve as intake airways as well as haulageways.

Practically all French bituminous-coal mines are very gassy, and the mining laws restrict the use of electricity underground. Electric installations that may produce arcs or sparks must be restricted to intake air.

Table 6 shows the number of mine locomotives in underground use in French coal mines in 1935, classified according to types of power.

TABLE 6. - Number of locomotives used underground in coal mines, 1935

District	Type of power			
			Electric	
	Diesel	Compressed air	Trolley	Battery type
Nord................	114	28	0	45
Pas-de-Calais........	160	35	7	54
Moselle..............	49	56	0	0
Loire................	22	4	15	2
Burgogne et Nivernais	0	0	0	46
Gard et Herault......	0	0	20	0
Tarn et Aveyron......	10	0	50	0
Bourbonnais-Auvergne.	2	0	11	0
Total..........	357	123	103	147

In 1937 the number of Diesel locomotives in use in all French coal mines had increased to 380, while the number of other types of locomotives had remained stationary. It should be noted in the 1935 statistics that the first 4 districts, which produced 80.7 percent of the domestic production, used only 22 trolley-type locomotives compared to 345 Diesel and 123 compressed-air type.

At one large mine using both Diesel and electric mine locomotives, trolley-type electric locomotives were used entirely in main haulage tunnels, which served as intake airways; storage-battery-type electric locomotives were used for gathering purposes, and Diesel locomotives were used interchangeably in any service. The mine ventilation was adequate to dilute and remove the exhaust fumes, but the use of washers with chemical absorbents on all Diesel locomotives was rigidly enforced by the mine inspectors. Labyrinth-type spark arresters were maintained on all locomotives; these were cleaned at the end of each shift.

French regulations stipulate that wherever Diesel locomotives are working underground in gassy or dusty mines the ventilating current must not be less than 2.6 cubic feet of air per second per brake-horsepower of all locomotives working in that circuit, and that a minimum of 70 cubic feet of air per second is required. The minimum velocity of the air should be 394 feet per minute (2 meters per second).

Tests must be made for carbon dioxide (CO_2) and carbon monoxide (CO) at least every 3 months on all locomotives operating under normal conditions. The samples are collected from the exhaust outlet with the motor running at normal operating speed and when the motor is idling. The carbon monoxide content of the final exhaust gas is said to average 0.1 percent when the engine is in normal operation and about 0.2 percent when idling. Most Diesel engines used underground are 4-cycle type, but a few 2-cycle types are still in use.

Fuel oil is required to have a flash point above 122° F., and any fuel oil taken underground must be in closed metallic barrels or in tank cars. The amount stored underground is required to be an indispensable minimum.

Italy and Sardinia

The coal deposits of the mainland of Italy are relatively unimportant, primarily because of the extremely poor quality of the coal, which averages about 5500 B.t.u. The Arsa coal field, near Trieste, is now in the possession of Yugoslavia, and the only other source of domestic coal is Sardinia.

The coal deposits of Sardinia are in the Province of Cagliera in the vicinity of the town of Carbonia. There are seven workable coal beds, which are badly folded and faulted; the dip of the beds varies from nearly horizontal to vertical, and in some places the dip is reversed. Several major faults, with displacements of over 500 feet, cut the coal beds into relatively small blocks, each of which is opened by a shaft for reasons of economy. All the mines are gassy.

The coal beds are opened by vertical shafts, with crosscuts driven to intersect the coal beds; the level interval depends on the dip of the coal beds. Entries are turned right and left from the crosscut tunnels and driven on the strike of the coal beds on about 1 percent grade in favor of the load. They are driven singly, and no provision is made to circulate the air until a connection is made with another level. The crosscut tunnels are used as intake airways; the ventilation is adequate on the haulageways but is very poor in the actual working faces.

The longwall system of mining is used, except where the coal dips too steeply, in which case an overhead open-stope method is used similar to metal-mining practice. Where the roof conditions are too hazardous to work longwall, the coal is mined by a modified room-and-pillar-method, with rooms 6 feet wide and pillars 12 feet wide.. The coal is hand-shoveled as much as 30 feet to a slope or to a loading station. In some instances, small scrapers are used to pull the coal to the loading station.

The coal is loaded by hand on shaking conveyors along the longwall face and taken directly to the mine cars or loaded upon belt conveyors in the entry and taken to a loading station near the crosscut tunnel. The shaking conveyors are driven with compressed-air motors.

Diesel locomotives are used exclusively for all types of service underground. The locomotives are equipped with spark arresters, and the exhaust fumes are washed first in water and then through a calcium chloride solution. Locomotives are not allowed to idle while in an entry but are permitted to do so in the haulage tunnels. The Diesel locomotives are of Italian manufacture and appear to be slow, but they will haul 35 to 50 mine cars of 1-ton capacity to the loading stations.

The ventilation in these mines is so poor that mine officials were questioned regarding the use of Diesel locomotives underground. However, the records do not show any accidents from the exhaust fumes, and the odor of the exhaust fumes was not noticeable in any of the haulage levels.

The mercury and pyrite mines were visited but the pyrite mines were not operating. Mine officials at the pyrite mines stated that Diesel locomotives were used on all mine levels that were ventilated but not on the levels where the air could not be circulated.

The Mount Amiata mercury mine is the largest mercury mine in Italy and one of the largest in the world. The ore is cinnabar, which occurs in large, irregular bodies. The ore is mined by the cut-and-fill system; loaded into cars by hand; and dumped into ore passes, which extend to the haulage level.

All mechanical transportation underground is by Diesel locomotives of Italian manufacture. Numerous openings to the surface provide adequate natural ventilation, and the Diesel locomotives operate without spark arresters or exhaust-fume washers. Mine officials say that Diesel locomotives have been in use for over 8 years without experiencing any trouble from the exhaust fumes.

Spain

Asturias Mining District - Province of Oviedo

The principal production from this district is obtained by three large companies; the coal is of the coking type and is used largely in the manufacture of steel in the Bilboa area. The mines of two companies are "captive mines", in that the entire production is used by the parent steel companies.

The coal beds are folded steeply, with many faults; the cross sections through the coal beds resemble those of the anthracite mines of Pennsylvania. The principal shaft for hoisting coal is sunk to the desired depth; and crosscut tunnels, or levels, are driven to intersect the various coal beds. The levels are spaced so as to produce 4,000,000 to 5,000,000 tons of coal from each level. Single entries are driven on the strike of the coal bed, and the coal is mined by a modified longwall method which resembles the overhead openstope system used in some metal mines. The coal is drawn from the stope by gravity and loaded into cars having a capacity of about 1 metric ton of raw coal. The loaded cars are dropped by gravity to a gathering yard in the entry.

Small Diesel locomotives, weighing about 5 tons, brings empty cars to the siding above the car loading point and take the loaded cars to the haulage tunnel to be handled by main-line locomotives. When it is necessary for the locomotive to wait in the entry for any reason, the locomotive operator immediately stops the engine; however, this is not done in the haulage tunnel. The entries observed are about 8 by 12 feet and are driven in rock and coal. The coal beds are seldom more than 5 feet thick, except in local areas. The ventilation in the entry seemed to be adequate, and the odor of exhaust fumes could not be detected. The ventilation of the working places in the overhead stop was entirely inadequate, and apparently no effort is made to course the ventilating air through the overhead working except through the small manways and the leakage at the loading points. The gathering locomotives handle 30 to 40 cars to the yard in the haulage tunnel.

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The crosscut tunnels are driven fairly large, about 9 by 10 feet to 10 by 12 feet in cross section; they are usually lined with brick or concrete blocks at the intersections of the coal beds and where the roof is not solid. The ventilation in the haulage tunnels is very good, as these tunnels are used as intake airways. Diesel locomotives weighing 8 to 10 tons haul 50 to 75 cars of coal to the mine shaft. Of the 12 main-line locomotives observed in the entire district, 5 were using the gas washers provided with equipment, and the washers had been removed from the remaining 7 locomotives owing "to the washer causing a reduction in power." The mine officials report that a larger volume of air is used to dissipate and dilute the exhaust fumes.

Puertollano District - Province of Castilla de Neuva

The coal beds of the Puertollano district form a basin with flat slopes and the beds are seldom faulted. Five coal beds are worked, and a sixth bed of bituminous shale underneath the coal beds is mined for the Distilleria de Callatraba, which manufactures fuel oil and gasoline of low quality.

The coal is mined by a modified longwall system, using shaking conveyors to transport the coal to the haulage entries. The mines are rated as nongassy, and both electric and Diesel locomotives are used; storage-battery-type electric locomotives and Diesels are used for gathering purposes.

The mine cars are small, have a capacity of 700 liters (25 cubic feet), and are said to hold about 0.6 ton of raw coal. The cars have no bumpers and are coupled with chains.

The Diesel locomotives are rated as 4-ton, 24-horsepower and are used entirely for gathering purposes. The locomotives operate only in intake air; the State mining regulations for the district require 4,000 liters (141 cubic feet) of air per second for each Diesel locomotive in use. This compares with the national laws which require 40 liters (1.4 cubic feet) of air per second for each worker; each mule or hose requires the air for three men; each internal-combustion engine must have 180 liters (6.4 cubic feet) of ventilating air per second. This amount of ventilating air exceeds the ventilation requirements of many countries.

Spain has not published statistics showing the number and types of mine locomotives used in underground mines.

Great Britain

Haulage in British coal mines long has been regarded as obsolete when compared with transportation standards of the United States and the mines of continental Europe. The Reed report gives the following information relative to comparative haulage efficiency:

> One haulage worker is required for every 50 tons of saleable coal mined in the United States; one haulage worker is required for every 20-25 tons of saleable coal mined in Holland; one haulage worker is required for every 5 tons of saleable coal mined in Britain.

The use of rope haulage and the steep track grades found in most British mines are responsible to a large extent for the conditions mentioned in the Reed report.

The use of internal-combustion engines underground in gassy coal mines was prohibited by the Ministry of Fuel and Power after several disastrous explosions occurred in the mines of continental Europe; furthermore, the mining regulations prohibited the use of trolley-type electric locomotives.

The necessity of using more efficient haulage units and the development of the Diesel locomotives in Germany and Belgium caused the Ministry of Fuel and Power to permit Diesel locomotives to be used underground provided prior, permission was obtained before the equipment was installed.

Among the regulations governing the use of Diesel locomotives at the Comrie colliery of the Fife Coal Co. the following are quoted:

1. The locomotives shall be used only on such roads as may be specified in writing by the Inspector of the Division.
2. The standards of ventilation in, and in the vicinity of, the roads on which the locomotive is permitted to be used shall be such that the firedamp content of the air entering these roads does not at any time when the locomotive is operating exceed one percent, and the firedamp content of the general body of the air in the roads themselves does not at any time when the locomotive is operating exceed 0.5 percent.
3. The gradient of the track shall not exceed 1 in 15.
4. The design and construction of the locomotives, including the inlet and exhaust systems, the lighting equipment and other electrical accessories, shall be of a type or types certified as flameproof by the Ministry of Fuel and Power, and all such parts shall be maintained in their designed condition.
5. A locomotive shall not be run into any unventilated dead end.
6. The engine shall not be kept running when a locomotive is stationary except for short periods for special purposes.
7. The exhaust gases from the locomotives shall be analyzed at least once in every 3 months and shall not at any time contain more than five parts per thousand of carbon monoxide.
8. Once in every 24 hours each locomotive shall be examined by a competent person appointed in writing by the manager, and the flameproof trap fitted to the exhaust opening of the engine shall be detached and replaced by a trap in clean condition.

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9. Once every week each locomotive shall be examined by a competent engineer, who shall see that it is in proper working order and that the flameproof trap fitted to the inlet opening of the engine and the inlet and exhaust valves of the engine are cleaned as often as may be necessary.

10. The speed of the trains shall not be allowed to exceed 15 miles per hour.

11. The oil used as fuel -

    (a) Shall have a flash point of not less than 150° F. as determined in the manner set forth in the current British Standard Specification (No. 209).

    (b) Shall only be taken underground in sufficient quantity for one day's working of each locomotive.

    (c) Shall be taken underground in strong, closed receptacles which will not leak.

12. The oil tanks shall be filled only at a properly appointed filling station, and adequate means shall be provided as far as possible to avoid spillage in the process of filling.

13. Each filling station shall have a floor of smooth concrete provided with a sill, and if the filling station is a room it shall also be -

    (a) ventilated with a through current of air;

    (b) provided with two separate means of egress;

    (c) constructed noninflammable material.

British manufacturers build Diesel locomotives with flameproof safety devices for underground use that range in size from 20 to 100 horsepower. One company reports the first Diesel locomotive of their manufacture was used underground in a British coal mine in July 1939.

One of the safety devices provided on these locomotives controls the operation of the locomotive by means of the water level in the exhaust conditioner; the fuel is cut off automatically from the engine if the water level falls below a certain level, and the brakes are applied automatically at the same time. This device does not function unless the conditioner is filled with water at the beginning of the shift. Rustless steel is used throughout in the manufacture of the conditioner to combat the highly corrosive action of the mine water.

Most British Diesel locomotives for underground use are equipped with gears to give four road speeds, as follows:

3¼ miles per hour on low gear
5 miles per hour on second gear
8½ miles per hour on third gear
12½ miles per hour on top gear

It is claimed that these locomotives will haul trains carrying 100 men up gradients of 1 in 20, and up to speeds of 8½ miles per hour on gradients of 1 in 100.

CONCLUSIONS

The use of Diesel locomotives for haulage purposes in European underground mines is successful in both gassy and nongassy coal mines and in metal mines, as is evidenced by the increasing number of this type of locomotive in service during successive years.

Mining conditions in European coal mines differ from those usually encountered in American mines; the coal beds are thinner and folded more steeply; the longwall system of mining is used almost exclusively; the coal beds are opened by crosscut tunnels driven from hoisting shafts; and the entries are driven on the strike of the coal beds.

Diesel and compressed-air locomotives are used in mines where electric types are prohibited by law or mining regulation because of the danger of an electric arc igniting possible accumulations of gas. The compressed-air locomotive is circumscribed in its application by the distance it can travel without returning to the high-pressure air station to recharge the storage tanks. The number of Diesel locomotives in use is increasing faster than either compressed-air or electric types, probably because of their adaptability and lower cost of operation.

The danger from sparks in Diesel-type locomotives is eliminated by the efficient labyrinth spark arresters, while the danger to humans from the toxic gases in the exhaust fumes is eliminated by excess ventilation, which dilutes and dissipates the gases. Washers to absorb and remove the toxic gases are required as an additional safeguard in some countries.

Diesel locomotives appear to be safer to use in underground gassy coal mines than electric locomotives provided that an excess amount of ventilating air is circulated through the haulageways. Diesel engines should not be permitted to idle in any place where there is not abundant air passing the unit. Provision for adequate ventilation to dilute and carry away the toxic gases from the exhaust fumes is more important than the use of washers or gas absorbers without providing increased ventilation since, in practice, the washers are often removed or are inoperative, which is not harmful if there is an adequate supply of ventilating air.